Conservation of Momentum in One Dimension

1) Why did cannons on 16th- to 19th-century warships need a rope around the back, tying them to the side of the ship?

– so once they fire the ball forward, the cannons didn't roll backwards too far

2) A 110-kg astronaut and a 4000.0-kg spacecraft are attached by a tethering cable. Both masses are motionless relative to an observer a slight distance away from the spacecraft. The astronaut wants to return to the spacecraft, so he pulls on the cable until his velocity changes to 0.80 m/s [toward the spacecraft] relative to the observer. What will be the change in velocity of the spacecraft? [0.022 m/s [towards the astronaut]]

$m_a = 110 kg$

$m_s = 4000.0 kg$

$v_a = 0 m/s$

$v_s = 0 m/s$

$v_a' = 0.80 m/s$

$v_s' = ?$

$$\vec{p} = \vec{p}'$$

$$\cancel{m_a \vec{v}_a} + \cancel{m_s \vec{v}_s} = m_a v_a' + m_s v_s'$$

$$-m_a v_a' = m_s v_s'$$

$$-\frac{m_a \vec{v}_a'}{m_s} = \vec{v}_s'$$

$$\vec{v}_s' = \frac{-110 kg (0.80 m/s)}{4000.0 kg}$$

$$\vec{v}_s' = -0.022 m/s$$

$$\vec{v}_s' = 0.022 m/s \text{ [towards astronaut]}$$

3) A 75-kg hunter in a stationary kayak throws a 0.72-kg harpoon at 12 m/s [right]. The mass of the kayak is 10.0 kg. What will be the velocity of the kayak and hunter immediately after the harpoon is released? [0.10 m/s [left]]

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$m_h = 75 kg$

$m_K = 10.0 kg$

$m_s = 0.72 kg$

$v_{hK} = 0 m/s$

$v_s = 0 m/s$

$v_s' = 12 m/s$

$v_{hK}' = ?$

$$\vec{p} = \vec{p}'$$

$$m_{hK} \cancel{\vec{v}_{hK}} + \cancel{m_s \vec{v}_s} = m_{HK} v_{HK}' + m_s v_s'$$

$$-\frac{m_s v_s'}{m_{HK}} = v_{HK}'$$

$$v_{HK}' = -\frac{0.72 kg (12 m/s)}{(75 kg + 10.0 kg)}$$

$$v_{HK}' = -0.10 m/s$$

$\therefore$ **$v_{HK} = 0.10 m/s$ [left]**

4) A student is standing on a stationary 2.3-kg skateboard. If the student jumps at a velocity of 0.37 m/s [forward], the velocity of the skateboard becomes 8.9 m/s [backward]. What is the mass of the student? [55 kg]

$\longrightarrow +$

$m_s = ?$
$m_b = 2.3\,kg$
$\vec{v}_s = 0\,m/s$
$\vec{v}_b = 0\,m/s$
$\vec{v}_s{}' = 0.37\,m/s$
$\vec{v}_b{}' = -8.9\,m/s$

$\vec{p} = \vec{p}\,'$

$m_s\vec{v}_s + m_b\vec{v}_b = m_s\vec{v}_s{}' + m_b\vec{v}_b{}'$

$\frac{-m_b\vec{v}_b{}'}{\vec{v}_s{}'} = m_s$

$m_s = \frac{-2.3\,kg(-8.9\,m/s)}{0.37\,m/s}$

$m_s = 55.324\,kg$

$m_s \approx 55\,kg$

5) A wooden block attached to a glider has a combined mass of 0.200 kg. Both the block and glider are at rest on a frictionless air track. A dart gun shoots a 0.012-kg dart into the block. The velocity of the block-dart system after collision is 0.78 m/s [right]. What was the velocity of the dart just before it hit the block? [14 m/s [right]]

N, E

6) A student on a skateboard, with a combined mass of 78.2 kg, is moving east at 1.60 m/s. As he goes by, the student skilfully scoops his 6.4-kg backpack from the bench where he had left it. What will be the velocity of the student immediately after the pickup? [1.5 m/s [E]]

$m_s = 78.2\,kg$
$\vec{v}_s = 1.60\,m/s$
$m_b = 6.4\,kg$
$\vec{v}_{bs} = ?$
$\vec{v}_b = 0\,m/s$

$\vec{p} = \vec{p}\,'$

$m_s\vec{v}_s + m_b\vec{v}_b = (m_s + m_b)\vec{v}_{bs}$

$\frac{m_s\vec{v}_s}{m_s + m_b} = \vec{v}_{bs}$

$\frac{78.2\,kg(1.60\,m/s)}{78.2\,kg + 6.4\,kg} = \vec{v}_{bs}$

$\vec{v}_{bs} = 1.47896\,m/s$

$\vec{v}_{bs} \approx 1.5\,m/s\,[E]$

N, E

7) A 1050-kg car at an intersection has a velocity of 2.65 m/s [N]. The car hits the rear of a stationary truck, and their bumpers lock together. The velocity of the car-truck system immediately after collision is 0.78 m/s [N]. What is the mass of the truck? [2.5 x 10^3 kg]

$m_c = 1050 kg$
$v_c = 2.65 m/s$
$m_T = ?$
$v_T = 0 m/s$
$v_{cT} = 0.78 m/s$

$\vec{p} = \vec{p}\,'$

$m_c v_c + m_T v_T = m_{cT} v_{cT}$

$m_c v_c + (m_c + m_T) v_{cT}$

$\frac{m_c v_c}{v_{cT}} = m_c + m_T$

$\frac{m_c v_c}{v_{cT}} - m_c = m_T$

$\frac{1050 kg (2.65 m/s)}{0.78 m/s} - 1050 kg = m_T$

$2517 kg = m_T$

$m_T \approx 2500 kg$

8) A basketball player and her wheelchair (player A) have a combined mass of 58 kg. She moves at 0.60 m/s [E] and pushes off a stationary player (player B) while jockeying for a position near the basket. Player A ends up moving at 0.20 m/s [W]. The combined mass of player B and her wheelchair is 85 kg. What will be player B's velocity immediately after the interaction? [0.55 m/s [E]]

9) A 110-kg Stampeders football fullback moving east at 1.80 m/s on a snowy playing field is struck by a 140-kg Eskimos defensive lineman moving west at 1.50 m/s. The fullback is bounced west at 0.250 m/s. What will be the velocity of the Eskimos defensive lineman just after impact? [0.11 m/s [E]]

10) A 72-kg snowboarder gliding at 1.6 m/s [E] bounces west at 0.84 m/s immediately after colliding with an 87-kg skier travelling at 1.4 m/s [W]. What will be the velocity of the skier just after impact? [0.62 m/s [E]]